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ABSTRACT

The report describes the principal orientations of the International Hydrological Programme, as well as the procedures suggested for its execution. The origin and justification of the programme are presented. The objectives of the 1975 programme are stated and the contents, which include the activities, themes, application of new techniques in hydrology are listed and discussed. The promotion of hydrology teaching and of practical training of hydrologists is stressed, and the activities planned in this sphere are presented. Recommendations on a long-term programme of international cooperation in the field of hydrology are discussed in the annex of this publication. (EB)

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Item 13.3 of the Provisional Agenda

## REPORT OF THE DIRECTOR-GENERAL ON THE LONG-TERM PROGRAMME IN THE FIELD OF HYDROLOGY

(International Hydrological Programme)

SUMMARY

The General Conference, at its sixteenth session, invited the Co-ordinating Council of the International Hydrological Decade to prepare a long-term programme of international co-operation in the field of hydrology and requested the Director-General to submit it to the General Conference at its seventeenth session with his recommendations, together with proposals concerning the procedures or machinery to ensure proper co-ordination of the planning and execution of the programme.

According to the terms of this resolution, the Director-General is submitting to the General Conference the present report describing the principal orientations of the International Hydrological Programme, as well as the procedures suggested for its execution.

The General Conference may wish to examine this report in connexion with draft resolution 2.323 and paragraphs 2327-2329 of document 17 C/5.

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## I. ORIGIN AND JUSTIFICATION OF THE PROGRAMME

1. Eight years ago, the General Conference of Unesco, at its thirteenth session, launched the International Hydrological Decade (IHD), (1965-1974), the programme of which was the first world-wide concerted effort to intensify studies in all branches of hydrology and to improve the training of hydrologists in order to enable each country to evaluate and develop better their water resources.

2. To supervise from the scientific and organizational points of view the implementation of the Decade programme and to co-ordinate international co-operation in the framework of this programme, the Unesco General Conference created a Co-ordinating Council, the secretariat of which is provided by Unesco. Consisting at the beginning in 1965 of 21 members, the Council is now composed, since 1970, of 30 members; it constitutes an original system of intergovernmental and inter-institutional co-operation which gives the opportunity of raising to a maximum the voluntary participation of Member States in a collective programme while maintaining to a minimum the international mechanism of co-ordination.

3. The programme of the International Hydrological Decade has been widely followed by Member States. Thus, 107 countries, in accordance with the recommendation of the General Conference, created National Committees for the Decade and made known their decision to participate in the IHD activities. It can be stated that the IHD programme stimulated to a large extent, throughout the world, the interest in an exhaustive study of water resources, a constituent element of the natural environment and an important factor of economic and social development.

4. The IHD programme, by its echo throughout Member States, has stimulated hydrological activities at national level, and has also encouraged regional co-operation which is indispensable for the study of the hydrological cycle on a large scale. The close co-operation established between National Committees of Scandinavian countries, of East European and of North American countries, and the organization of regional meetings of National Committees, i.e. as held in South America in 1967, in Asia in 1970, and in Africa in 1971, are good examples.

5. The International Hydrological Decade has been greatly supported by international organizations. The United Nations, FAO, WMO, WHO and IAEA took, from the beginning, a great interest in the International Hydrological Decade programme, to which they contributed in various ways: by participating in the work of the Co-ordinating Council and its working groups; by providing the technical secretariat of some working groups and panels; by the preparation of reports on specific projects of the Decade programme and of relevant publications; and by participating in the programme of symposia, etc.

The same holds true for scientific non-governmental organizations - such as the International Association of Hydrological Sciences, the International Association of Hydrogeologists, the Scientific Committee on Water Problems (COWAR) of ICSU, the International Association for Hydraulic Research, the International Commission on Irrigation and Drainage - which have taken an active part in the scientific programme of IHD, acting for some projects as scientific advisers.

The Co-ordinating Council of the Decade, while being under the jurisdiction of the Unesco General Conference, has proved to be an appropriate forum for a general exchange of views on the development of hydrological activities at national, regional and international levels.

6. Perceptible progress has been made at national, regional or international level as regards the research programme adopted by the Council and concerning the study of hydrological processes (precipitation, evaporation, soil moisture, surface and groundwater runoff, etc.), the study of various geographical or climatological environments (limestone terrains, lakes, deltas, glaciers, etc.) and methodological problems (methods and mathematical models, use of nuclear techniques, etc.).

7. Considerable progress has been achieved in the field of general and practical training of hydrologists and technicians. Eight Unesco-sponsored post-graduate courses have been organized, specially for developing countries, in Austria, Spain, Hungary, India, Israel, Italy, Netherlands and Czechoslovakia; up to now they have been attended by about 750 students. Specialization courses for hydrology professors and research workers have been organized since 1969 in the United States, Netherlands and the USSR with hundreds of participants. Other courses on snow and ice have taken place in Sweden and in Chile. Unesco has also organized regional training courses for technicians

in Mali, Tunisia and Kenya, which have been attended by nearly one hundred participants. The thousand specialists trained by these various courses, the majority being nationals from developing countries, thus constitute a valuable asset for the hydrological activities of their respective countries, which is undoubtedly one of the most appreciable results of the Decade.

8. The Decade gave rise to an important increase in publications and exchanges of information. From the beginning of IHD, Unesco has published on its own or in co-operation with other organizations about twenty publications including methodological guides on representative and experimental basins and on groundwater, technical papers on snow and ice, data on Decade stations and discharges of main rivers of the world, proceedings of symposia, and the first sheet of the Hydrogeological Map of Europe, etc. About fifteen other major publications will be issued before the end of the Decade. The World Meteorological Organization has also published, as a contribution to the Decade, a series of reports on IHD projects which fall within the field of competence of WMO. Other publications concerning the IHD programme have been prepared by FAO and IAEA. Symposia have also proved to be an efficient means for the exchange of views and for the dissemination of experiences acquired in the main fields of scientific hydrology. From 1965 up to this date about twenty symposia have been held under the auspices of the International Hydrological Decade.

9. Despite the progress made during the first eight years of the Decade, it must be noted that the gap existing in the field of hydrology between advanced and developing countries is increasing. On the one hand there is a rapid development of new techniques - such as the use of satellites for the study of hydrological phenomena - which facilitates the global approach to problems concerning the water cycle but from which many countries cannot benefit; on the other hand, some countries have neither the hydrometric networks required for the collection of basic data related to their water resources, nor the appropriate hydrological services necessary for their analysis and interpretation. To this organizational and material deficiency is added an acute shortage of hydrology specialists, which has only been partially filled by the training courses organized under the aegis of IHD. Finally, even if the establishment of National Committees for the Decade provided a large number of countries, for the first time, with an organism entrusted with the co-ordinating of hydrological activities at national level, it must nevertheless be noted that some of these Committees are still rather symbolical, their influence and efficiency being very restricted.

10. Despite the considerable progress made in the framework of this programme, it is obvious that a single decade cannot solve all the problems concerning the scientific development of hydrology and its numerous practical applications. On the other hand, the impulse given by the Decade for a more intensive study of the water resources of our planet should be pursued so that the efforts already made will be fruitful.

11. This fact has been fully recognized by the International Conference on the Practical and Scientific Results of the International Hydrological Decade and on International Co-operation in Hydrology which was convened by Unesco and organized with the co-operation of WMO in December 1969. This "Mid-Decade" Conference:

(a) invited Unesco to ensure the continuation, after the end of the Decade, of its activities in the field of hydrology;

(b) invited the Co-ordinating Council to prepare, in co-operation with the international organizations concerned, a long-term programme of intergovernmental co-operation in the field of hydrology;

(c) requested the Director-General to plan, in consultation with organizations concerned, a procedure or machinery to ensure permanent co-operation in the execution of this programme.

## II. PREPARATION OF THE PROGRAMME

12. The General Conference of Unesco approved, at its sixteenth session, the recommendations of the Mid-Decade Conference, and decided (resolution 2.335):

(i) to invite the Co-ordinating Council for the International Hydrological Decade "to prepare, with the assistance of the Director-General and the participation of the international organizations concerned, a long-term programme of international co-operation in the field of hydrology, to be submitted, together with comments and recommendations of the Director-General, to the General Conference at its seventeenth session";

(ii) to request the Director-General "to submit to the General Conference, at its seventeenth session, after consultation with the organizations of the United Nations system concerned and with competent international non-governmental organizations, proposals concerning procedures or machinery designed to ensure proper co-ordination in the planning and implementation of a long-term programme in the field of hydrology".

13. Following this resolution, the Co-ordinating Council set up an ad hoc working group and instructed it to prepare the outline of a long-term programme, taking as a basis the general guidelines drawn up by the Mid-Decade Conference as well as the suggestions of National Committees of IHD regarding the possible contents of the long-term programme. The group completed its work during the period December 1970 to June 1971.

The project prepared by the ad hoc working group was finally approved by the Council at its seventeenth session (22-26 November 1971). This project, in the form indicated in Annex XVIII to the final report of the Seventh Session of the Co-ordinating Council (document SC/MD/27), is reproduced as annex to the present document.

The long-term programme proposed by the Council covers scientific investigations and practical applications which fall under three main categories:

water balance and water resource assessments at basin, national, regional and ultimately global levels;

effects of human activity on the hydrological cycle, including quantity and quality effects on surface and groundwater;

application of new developments in hydrology, including sensing, processing and analysing of data, forecasting, mathematical modelling and system analysis;

as well as promotional activities in the following fields:

education and training;

exchange of information;

technical assistance;

regional co-operation.

14. The recommendations of the Council of the International Hydrological Decade should be considered as an outline concerning the development of international co-operation in the field of hydrology in general. The major orientations of the programme are directed towards the promotion of research, exchange of information, education and training, thus corresponding to the fundamental objectives pursued by Unesco. Nevertheless, the recommendations of the Council also refer to the development of hydrological networks and methods of measurement of hydrological elements, as well as to certain applications of hydrology for the development of irrigation and water supply of urban and industrial areas; that is to say to problems dealt with within the framework of programmes conducted by other organizations of the United Nations system, such as WMO, FAO, WHO, etc.

The implementation of the recommendations of the Co-ordinating Council thus necessarily bears an inter-agency nature, which has been underlined by the working group of the ACC Sub-Committee on Water Resources Development (January 1972).

15. Following the resolution of the General Conference requesting him to submit "proposals concerning procedures or machinery designed to ensure proper co-ordination in the planning and implementation of a long-term programme in the field of hydrology", the Director-General has, for two years, been undertaking consultations with Member States, as well as with interested organizations of the United Nations system and international non-governmental organizations.

16. In the unanimous opinion of Member States - as expressed at the sessions of the Co-ordinating Council of the International Hydrological Decade and at regional meetings of National Committees for the Decade held in Asia and in Africa in 1970 and 1971 respectively, as well as in comments received from some countries - the co-ordinating mechanism of the long-term hydrological programme must rest on two basic elements, which have already proved to be useful during the International Hydrological Decade:

(i) the existence in each participating country of a National Committee entrusted with the preparation and execution of its national hydrological programme and with its contribution to the activities undertaken at the international scale;

(ii) the establishment of an Intergovernmental Council responsible for supervising the execution of the programme at the international level, for maintaining its unity, and for incorporating national contributions.

17. The United Nations, FAO, WMO, WHO and IAEA have shown their interest in the programme and have contributed to certain phases of its preparation.

Nevertheless, these organizations have generally indicated that it was premature to define their practical possibilities of participating in the programme which was to be approved by the General Conference of Unesco.

The consultations undertaken showed the absence of an adequate formula which would enable an intergovernmental body to carry out the technical co-ordination of a general programme in hydrology, some parts of which would be executed by various organizations of the United Nations system. While the general co-ordination of the activities of these organizations would continue to be provided by the Sub-Committee for Water Resources Development of the Administrative Committee on Co-ordination, bilateral arrangements between the secretariats would be encouraged in order to harmonize the execution of their respective programmes in hydrology.

To this end, some organizations - namely the United Nations, FAO and WMO - have been particularly keen to point out that, in their opinion, the Intergovernmental Council which would be established by the General Conference to supervise the International Hydrological Programme should not be entrusted with the implementation of the particular aspects of this programme which go beyond the field of competence of Unesco.

18. The international non-governmental organizations - such as the International Association of Hydrological Sciences, the International Association of Hydrogeologists, the Scientific Committee on Water Problems (COWAR) of ICSU, the International Association for Hydraulic Research, and the International Commission on Irrigation and Drainage - have expressed their strong support to the project of the International Hydrological Programme of Unesco and their intention to participate actively in this programme, according to their possibilities.

## III. ACTION PROPOSED BY THE DIRECTOR-GENERAL

19. Based on the recommendations of the International Mid-Decade Conference and of the Co-ordinating Council of the International Hydrological Decade, and taking into account consultations with the other international organizations concerned, the Director-General submits to the General Conference the following proposals:*

### A. Launching in 1975 of the International Hydrological Programme

#### Objectives of the programme

20. The Director-General proposes that the General Conference approve the launching, from 1975, of an intergovernmental long-term programme in the field of hydrology, to be known as the International Hydrological Programme. This programme, focused on the scientific and educational aspects of hydrology, will have the following main objectives:

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* The substance of these proposals is reflected in proposed resolution 2.323 contained in document 17 C/5.

to provide a scientific framework for the general development of hydrological activities;

to further the study of the hydrological cycle and to improve the scientific methodology for assessment of the water resources throughout the world, thus contributing to their rational use;

to evaluate the environmental implications of changes introduced by man's activities in the water cycle;

to promote the exchange of information on hydrological research and on new developments in hydrology;

to promote education and training in hydrology;

to assist Member States in the organization and development of their national hydrological activities.

21. The International Hydrological Programme will take its place among the other programmes of intergovernmental co-operation launched by Unesco in the field of environmental sciences, such as the programme on Man and the Biosphere, the programme of the Intergovernmental Oceanographic Commission and the Geological Correlation Programme. It will constitute a particular aspect of the Organization's long-term efforts with a view to reaching a better knowledge of natural resources and a better understanding of the relations between man and his environment, and will thus contribute, by means of science, education and information, to control these relations and use the natural resources for the progress of human society. The programme will also contribute to the implementation of some objectives established by the United Nations Conference on the Environment (Stockholm, 1972).

B. Contents of the programme

22. The activities included in the programme could be divided into the following categories:

(i) international research projects;

(ii) development of the educational system in hydrology;

(iii) exchange of information on hydrological research and progress of hydrology;

(iv) promotion of regional co-operation.

(i) International research projects

23. A scientific long-term programme must be sufficiently flexible to enable continuous changes in its research themes according to the development of science and to the practical needs of the society. This must be taken into account when planning the International Hydrological Programme (see paragraph 20). Nevertheless, it can be considered that for a relatively long period research themes will be defined particularly in the following spheres:

water balance;

effects of human activities on the water cycle;

applications of new techniques in hydrology.

24. The studies concerning the water balance will include:

improvement of methods of computation of the balance components from hydrometeorological and hydrogeological data;

detailed study of the water balance structure in specific environments by means of representative basins and establishment and methods for extrapolating balances assessed in these basins to water balances of large basins;

assessment of water balances at national, continental and global scale;

fluctuations of balance components in space and time.

Special attention will be given to the least known balance components, such as evaporation, water vapour transport in the atmosphere, water storage in soils, exchanges between surface water and groundwater.

25. The study of effects of human activities on hydrological factors, pertaining both to quantity and quality, will include in particular:

effects of the agricultural use of grounds and of the exploitation of forests on the water cycle and on the transport of sediments;

effects of the irrigation and drainage development on the surface and groundwater régime;

effects of urbanization;

changes in the hydrological régime due to hydraulic works;

diffusion and dilution of waste waters in rivers, lakes and reservoirs and self-purification processes;

effects of thermal pollution;

effects of local changes in the water cycle on water balances of a large territory;

development of the network of experimental basins so as to enable the differential evaluation of human activities on the various hydrological parameters.

26. The application of new techniques in hydrology will include in particular:

improvement of the water cycle models;

development of stochastic models of the hydrological series;

development of remote sensing techniques and in particular the use of satellites in hydrology;

use of nuclear techniques in hydrology.

27. The study of some selected subjects in the traditional fields of hydrology such as flood and low water parameters, hydrological problems of snow and ice, sediment transport, etc., will be continued.

(ii) Development of the educational system in hydrology

28. Hydrology, in its present meaning, is very recent, not only as a science but mainly as a specific profession. The need for hydrological personnel at all levels is felt in most countries and the shortage of hydrological specialists constitutes the main obstacle to the development of hydrological activities in many developing countries.

The promotion of hydrology teaching and of practical training of hydrologists will remain a particularly important field of the International Hydrological Programme.

The activities planned in this sphere will aim at:

promoting the training of hydrological personnel at all levels by means of international courses, regional courses and by creating national training centres in developing countries;

developing correspondence courses;

preparing and disseminating typical curricula for the training of hydrological personnel at various levels;

modernizing the teaching of hydrology in the light of scientific and technical progress, taking into account the effects of hydrology on the environment and its applications to water resources management;

studying and disseminating the experience gained in the use of teaching aids in hydrology (audio-visual aids, models, films, etc.).

(iii) Exchange of information

29. The exchange of information on the results of research and on the progress realized in hydrology in the various countries will constitute an essential aspect of the international co-operation in the framework of the programme.

The exchange of information will particularly concern

information on the past and on-going research in various countries;

multilingual thesauri, handbooks and manuals;

computer programmes used in various hydrological problems;

study programmes on representative and experimental basins.

30. International symposia will be periodically organized to enable wide exchange of views on topics of common interest. The organization of regional conferences and symposia will also be encouraged.

(iv) Regional co-operation

31. The International Hydrological Decade has stimulated bilateral and multilateral investigations, particularly among countries sharing river or groundwater basins. One of the objectives of the long-term programme is to encourage countries to develop such activities and to increase the assistance to be provided to them.

The practice of organizing periodic regional meetings of the National Hydrological Committees should be continued and supported. These meetings will serve to identify regional projects of common interest and to make concrete suggestions for their implementation. Support should also be provided for regional conferences, meetings, training courses, working groups, seminars, etc., organized by other organizations interested in hydrology.

Bilateral or multilateral co-operative studies should be made of important river and groundwater basins, representative and experimental basins, on aspects of common interest.

Regional projects should be developed as a contribution to global studies carried out in the framework of the long-term programme, such as:

computation of regional water balances;

computation of a 30-year comprehensive water balance;

development of extrapolation techniques to ungauged catchments.

Encouragement should be given to the development of training, research and exchange facilities, such as documentation centres, at regional and sub-regional levels.

C. Procedures for the execution of the programme

National Committees

32. The International Hydrological Programme must be of an essentially intergovernmental nature, i.e. the responsibility for its execution mainly falls on Member States, Unesco acting as a catalyser in supporting the programme in general.

It is thus desirable that, as for the International Hydrological Decade, each participating country be able to establish a National Committee entrusted with the definition of its contribution to the International Programme, and the organization and supervision of the execution of its national hydrological programme. It is, of course, up to each country to determine the rôle which its National Committee has to play, taking into account, on the one hand, the priority objectives of the scientific, economic and social development of the country and, on the other hand, the experience gained by the existing Decade National Committee which could, in fact, be re-established on a permanent basis. Whenever possible, it would be preferable to give to National Hydrological Committees, broader competence for the co-ordination of all hydrological activities at national level, including the participation of the given country in the various hydrology programmes conducted by other international organizations.

The Intergovernmental Council

33. The existence within Unesco of an intergovernmental co-ordinating body seems useful for maintaining the unity of the International Programme and for supervising its general execution. The establishment of a relatively limited Intergovernmental Council, composed of thirty representatives of Member States, periodically selected by the General Conference, taking into account equitable geographical distribution and appropriate rotation, seems to be an adequate structure, already used with success for Unesco intergovernmental programmes, such as the International Hydrological Decade and Man and the Biosphere.

34. The Council will meet at least every two years. It will elect a bureau composed of five to seven members, entrusted with the supervision of the implementation of the Council decisions. The Council will also have the faculty to create committees and working groups to study particular aspects of the programme.

35. Established by the General Conference, this body should not have functions exceeding the field of activity of Unesco itself and consequently its competence should not enter spheres pertaining to other organizations of the United Nations system. Nor should it substitute the procedures established in the framework of this system for the co-ordination of activities relating to water resources.

On the other hand, as all the interested international organizations will be invited to participate in the work of the Council, it could be used as an international forum for a periodical exchange of views on the general development of hydrological activities at international level.

Planning of activities

36. The International Hydrological Programme will be executed through medium-term successive phases. The programme being an integrant part of the whole Unesco programme, the Director-General proposes that the duration of these phases be of six years to coincide with the medium-term general planning of the activities of the Organization.

The contents of the sexennial phases prepared by the Intergovernmental Council would be examined at intergovernmental conferences gathering all participating countries and which will be convened at six-year intervals to evaluate the results achieved during the previous period and to define the orientation of the proposed programme for the next phase.

It should then be up to the Director-General to determine to what extent and in what way these proposals could be incorporated in the general economy of the draft of short- and medium-term Unesco programmes, and to submit his own recommendations to the General Conference.

D. Participation of other international organizations in the programme

Relations with other programmes

37. Due to the very important implications of the scientific and educational aspects for the general development of hydrology, the competent organizations of the United Nations system dealing with the operational aspects of hydrology or its applications to the practical utilization of water will be invited to participate in the programme, which would only benefit from this participation.

It is evident that it will be up to each interested organization to decide upon its possible contribution to the programme. The contributions, as for the International Hydrological Decade, could take various forms, from simple representation at the meetings of the Intergovernmental Council and its bodies to the execution of some projects included in the International Hydrological Programme.

It would be advisable to mention in the future statutes of the Council that the periodic reports on its activities presented to the Unesco General Conference also be sent to other international organizations participating in the International Hydrological Programme, in order to enable their constitutional bodies to take the necessary decisions concerning their participation in the activities of the International Hydrological Programme.

38. The participation of the organizations of the United Nations system in the activities of the Intergovernmental Council of the International Hydrological Programme will undoubtedly facilitate the exchange of information and the harmonization of the various programmes in the field of water resources conducted by these organizations and will enable the members of the Council to have a more complete picture of all the activities undertaken by the United Nations system in this sphere.

This will not at all dispense with or reduce the need for other forms of co-ordination and consultation between these organizations.

39. The International Hydrological Programme submitted by the Director-General to the General Conference - as well as the on-going programme of the International Hydrological Decade - does not constitute the only programme of international co-operation in the field of hydrology.

Therefore, the World Meteorological Organization, at its sixth Congress (April 1971), defined its own programme in "operational hydrology" including in particular the design and functioning of hydrological networks, the development and standardization of instruments and methods of observation, the processing of hydrological data, and techniques of hydrological forecasting. The United Nations, FAO and WHO are mainly interested in the application of hydrology to the various aspects of water use, while IAEA deals with the application of nuclear techniques in the field of water resources.

The Unesco International Hydrological Programme could neither supersede these parallel programmes nor try to absorb them. By its very extensive scope, it could, however, provide a scientific framework for the progress of hydrology as a whole; for this reason, the programme should remain open to active participation of the various international organizations concerned.

40. The general aspects concerning the co-ordination of the activities of the organizations of the United Nations system in the field of water, including hydrology, have been, up to now, suitably solved by the ACC Sub-Committee on Water Resources Development and would remain, in the future, under its responsibility.

41. On the other hand, the development of bilateral co-operation between the interested organizations could contribute to better harmonization of the technical aspects of the respective hydrology programmes.

Such co-operation is particularly important between Unesco and WMO which have developed large hydrology programmes and established intergovernmental bodies to co-ordinate them.

In this spirit, the Director-General proposed to the Secretary-General of WMO at the beginning of 1972 that a working agreement be concluded on Unesco/WMO co-operation in the field of hydrology.

42. One of the points of this proposed working agreement between Unesco and WMO concerns the joint convening, at regular intervals, of international conferences, like those mentioned in paragraph 36 above.

The application of this principle and the co-operation of other international organizations would enable such intergovernmental conferences to have an overall view on all the specific programmes in the field of hydrology and result in the definition of a general framework for international co-operation in this field, as conceived by the Co-ordinating Council of the International Hydrological Decade (paragraph 14 above).

43. The principles of the working agreement, in the form proposed by the Director-General, have been approved by the WMO Executive Committee at its twenty-fourth session (May 1972), which authorized the Secretary-General of WMO to finalize the agreement with the Director-General.

On the other hand, the Unesco Executive Board, at its 89th session, has been informed by the Director-General on the envisaged agreement and expressed its support for the joint convening, in 1974, by Unesco and WMO, of an international conference in the field of hydrology (cf. paragraph 5).

44. From the purely scientific point of view, the objectives of the International Hydrological Programme coincide with those of the scientific non-governmental organizations already mentioned in paragraph 5. It thus seems logical that these organizations be invited to participate in the long-term programme in the same way in which they presently participate in the International Hydrological Decade programme. The organizations concerned could continue to act as scientific advisers for various projects of the International Hydrological Programme and even be fully entrusted with the implementation of some of them.

45. Appropriate co-ordination should be established with the related Unesco programmes, such as Man and the Biosphere and the programme of the Intergovernmental Oceanographic Commission.

As regards the programme on Man and the Biosphere, this programme could benefit from the results of research undertaken in the framework of the International Hydrological Programme, on the implications of hydrology on the environment.

Arrangements between the Intergovernmental Oceanographic Commission and the Intergovernmental Council of the International Hydrological Programme will enable the study of contact problems, such as the water balance of oceans and some problems concerning the river mouth zones.

46. The recommendations of the United Nations Conference on the Environment (Stockholm, 1972) concerning the management of natural resources gave an important place to water, it being considered an essential element of the environment. The recommendations refer, among others, to the general assessment of water resources, to the development of integrated policies for the development of water resources, to the prevention of pollution and to other environmental aspects of water resources management, to the promotion of research and training in the field of water, and to the development of an appropriate institutional framework for water resources development.

It is obvious that, as already mentioned in paragraph 21, the International Hydrological Programme will be able to make an efficient contribution to the implementation of these recommendations. Appropriate relations should consequently be established between the Intergovernmental Council of the International Hydrological Programme and the institutional mechanism which would be set up by the United Nations as a follow-up to the Conference on the Environment.

E. Preparatory activities (1973-1974)

47. The approval by the General Conference, at its seventeenth session, of the launching in 1975 of the International Hydrological Programme, as well as the main orientations of this programme, will enable the Secretariat to undertake in good time the necessary preparatory activities.

In fact, the International Hydrological Programme is not a completely new programme; in some respects, it can be considered as a continuation of the International Hydrological Decade. For this reason - without prejudicing the completion of the Decade programme - it is necessary to consider the period 1973-1974 as a progressive transitory period of the International Hydrological Decade activities towards the long-term hydrological programme.

The Co-ordinating Council of the International Hydrological Decade has, in fact, already undertaken preparatory work to define the long-term programme; its working groups could be entrusted, within the next two years, besides the drafting of the final activity reports, with the preparation of detailed proposals for similar projects to be included in the International Hydrological Programme.

Other proposals will be prepared by the Secretariat with the assistance of consultants.

48. The measures to be taken in each country for the strengthening of IHD Committees in view of their continuation - or eventual reorganization - and transformation into permanent committees for the International Hydrological Programme, have a major importance.

In this respect the Director-General proposes to the General Conference that a recommendation be addressed to Member States (cf. item 5 of resolution 2.323 proposed in document 17 C/5).

49. Negotiations will be pursued with the international organizations concerned with a view to defining the conditions of their participation in the International Hydrological Programme.

50. According to the principles stated in paragraphs 36 and 42, the Director-General, with the agreement of the Executive Board, at its 89th session,* proposes to the General Conference to approve the joint convening by Unesco and WMO and in co-operation with other interested international organizations of an intergovernmental conference (category II) on the results of the International Hydrological Decade and on future programmes in hydrology to be conducted by Unesco and WMO.

The recommendations of these conferences will be submitted to the General Conference of Unesco and to the WMO Congress.

As regards the Unesco International Hydrological Programme, the Intergovernmental Conference will have to propose a programme for the first sexennial phase (1975-1980).

The General Conference will examine, at its eighteenth session, the proposals of the Director-General following the recommendations of the Intergovernmental Conference.

51. The Director-General will submit to the General Conference, also at its eighteenth session, his proposals concerning the statutes of the Intergovernmental Council of the International Hydrological Programme.

52. The Intergovernmental Council of the International Hydrological Programme will meet for the first time at the beginning of 1975. At that time, it will have to take appropriate measures to start the execution of the first phase of the International Hydrological Programme, in the form decided by the General Conference at its eighteenth session, in the light of recommendations adopted by the 1974 Intergovernmental Conference.

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* The Executive Board,

1. Recommends that the General Conference give favourable consideration to resolution 2.323 (document 17 C/5), para. 6 (a) of the latter being amended, as proposed by the Director-General, to read as follows:

"To convene in 1974, jointly with the World Meteorological Organization and in collaboration with other interested organizations of the United Nations system, an international conference to review the main results of the International Hydrological Decade and to prepare an outline International Hydrological Programme for the period 1975-1980, to be submitted to the General Conference at its eighteenth session, and also a draft plan concerning WMO's activities in the field of operational hydrology".

ANNEX

# RECOMMENDATIONS ON A LONG-TERM PROGRAMME OF INTERNATIONAL CO-OPERATION IN THE FIELD OF HYDROLOGY

adopted by the Co-ordinating Council
of the International Hydrological Decade
at its seventh session (22-26 November 1971)

## FOREWORD

The International Conference on the Practical and Scientific Results of the International Hydrological Decade and on International Co-operation in Hydrology (Mid-Decade Conference) held in December 1969 in Paris, recognizing the necessity for long-term international co-operation in the field of hydrology, requested the Co-ordinating Council of the International Hydrological Decade (IHD) (heretofore called Council), to prepare, in collaboration with interested international organizations, a plan for a long-term programme of regional and world-wide co-operation in hydrology based on the discussions and the relevant documents adopted by the Conference (resolutions 30, 31 and 32).

Concurrently, the Mid-Decade Conference recommended "that the international governmental and non-governmental organizations be asked to continue and intensify their activities in the field of hydrology, bearing responsibility for the hydrological activities in their own specific fields"; and requested ".... the Director-General, in consultation with the Co-ordinating Council of the IHD and in co-operation with the international governmental and non-governmental organizations concerned, to consider and plan a procedure or machinery for future co-operation in the long-term hydrological programme...." (resolution 31). The Mid-Decade Conference also called for maintenance and improvement of national hydrological committees by Member States "as one of the essential parts of the future system of collaboration in hydrological investigations...." (resolution 32).

In response to resolution 31 of the Mid-Decade Conference, the Director-General invited the United Nations, IAEA, WHO, WMO and FAO to present their views on a long-term programme of international co-operation in hydrology and on their own long-term plans in that part of hydrology falling within their responsibilities. By similar letter of 12 June 1970, ICSU, IASH, ICID, IAHR and IAH were invited to make a similar response. The replies of various organizations to the above letters were circulated during the sixth session of the Co-ordinating Council of the IHD (Document SC/IHD/33). Meanwhile, discussions with representatives of these agencies on "a procedure or plan for implementation" are continuing.

At its sixth session in July 1970, the Council reviewed the resolutions of the Mid-Decade Conference concerning the establishment of a long-term programme. It decided to set up an ad-hoc working group to prepare the programme for presentation at the Council's seventh session and invited the National Committees for the IHD to submit their recommendations for a long-term programme in hydrology (resolution VI.11).

At its sixteenth session (October-November 1970), the General Conference of Unesco approved the recommendations of the Mid-Decade Conference and of the Co-ordinating Council and invited the Co-ordinating Council to prepare, with the assistance of the Director-General of Unesco and with the participation of the international organizations concerned, a long-term programme of international co-operation in the field of hydrology. The General Conference also requested the Director-General to submit his observations and recommendations to its seventeenth session, in October-November 1972.

The General Conference has also requested the Director-General of Unesco to submit to its seventeenth session, after consultation with the organizations of the United Nations system concerned and with competent international non-governmental bodies, proposals for ensuring the necessary co-ordination in the planning and implementation of the long-term programme.

The Council also decided that the working group would be composed of experts from the following member countries: Brazil, France, India, Poland, Tunisia, United Kingdom, United States of America and USSR, and invited interested international governmental and non-governmental organizations to participate in the working group.

The Council further decided that the working group should prepare a general outline of the long-term programme, taking as a basis the "Suggested basic guidelines for an exchange of opinions on a long-term plan of action in the field of hydrology", approved by the Mid-Decade Conference (document SC/MD/18, Annex IV, Final Report of the Mid-Decade Conference).

In accordance with the decisions of the Council, the Secretariat invited all National Committees to send their proposals relating to the long-term programme for the use of the working group in the preparation of its report.

This present report on a Long-Term Programme of International Co-operation in Hydrology has been prepared by the ad-hoc working group. The working group based its work on the general guidelines issued by the Mid-Decade Conference, on suggestions received from National Committees of the IHD concerning the possible content of the Long-Term Programme and on contributions prepared by the members of the working group themselves.

Considering the actions of Unesco and of other intergovernmental and non-governmental agencies, the following document describes in some details the technical content of a programme in which international co-operation is needed. The working group identified water balances problems, the effect of man's activities on water cycle and hydrological factors and new developments in hydrology, as the principal major items for continuing international co-operation.

The draft report of the ad-hoc working group was discussed by the Co-ordinating Council at its seventh session and was amended in the light of comments received from National Committees for the IHD and of the Council's discussion, and was subsequently approved by the Council.

## 1. INTRODUCTION AND SUMMARY

### 1.1 The need for international co-operation in the field of hydrology

1.1.1 International co-operation in hydrology, supported by non-governmental and intergovernmental bodies, and in particular by a number of Specialized Agencies of the United Nations, has existed for many years. The initial response to the IHD showed that governments were strongly interested in more dynamic and better co-ordinated action. The IHD programme cannot solve all important questions - thus research on means for their solution should be pursued.

1.1.2 Today, in the light of the experience gained and looking ahead to a long-term programme, there is a need to study carefully and define as accurately as possible the main problems which require international co-operation.

1.1.3 The following aspects are taken into account in the preparation of the long-term programme.

1.1.3.1 Economic and social development entail increasing demands for water which, in the absence of care in utilization of water and of protection of water resources, result in a depletion of water resources in certain areas and an increase in the volume of waste materials produced, thus causing more rapid pollution of natural waters.

1.1.3.2 The interrelationships between elements of the water balance and other natural components (climate, soils, vegetation) call for permanent research at the national, regional and international levels.

1.1.3.3 The Mid-Decade Conference underlined the need for the development of standard methods for the establishment of water balances, first on a national scale and subsequently for important large river basins and continents, as a basis for the solution of practical problems in planning the use of water resources. The natural hydrological cycle spans large areas of the globe; therefore regional and international collaboration is necessary for the study of its mechanism.

1.1.3.4 The present network of hydrological stations in some countries is not sufficient either for the evaluation of the quantity and quality of water resources or for the establishment of water balances and hydrological forecasting. In connexion with this, many countries, especially the developing ones, require technical assistance to design, develop and equip networks and to train technical personnel. Adequate assistance must be provided to fill these needs within the framework of a long-term programme in hydrology.

1.1.3.5 Future research on the effects of human activity on the hydrological processes and on the quality of water are equally important. During the Mid-Decade Conference, attention was drawn to the fact that the complexity of the problem of man's influence on water resources made it difficult for many individual countries to carry out this research on their own. Further, man's activity in one part of a region could influence the hydrological régime and water quality of another part of the same region, situated in another country or even in several other countries. Principally for this reason it is essential that countries co-operate as much as possible at regional level.

1.1.3.6 In implementing the long-term programme due consideration should be given to other international programmes related to the investigation of the hydrological cycle, water resource development and protection, such as the Programme on Man and the Biosphere (MAB), the Global Atmospheric Research Programme (GARP), and others.

1.2 Objectives

1.2.1 The goal of the long-range programme is the improvement, through international co-operation, of the studies of water resources and water quality as well as the enhancement of national capabilities for the creation of scientific fundamentals for more rational utilization of water and its protection against pollution.

1.2.2 Implementation of the programme should create, directly or indirectly, a system of selected observing and monitoring stations which can provide information on hydrological elements and their variations with time and location throughout the world and so result in the collection of factual information useful for scientific study and water resources planning.

1.2.3 Investigation of large-scale processes of moisture transfer in the atmosphere; obtaining data about precipitation, evaporation, surface run-off and the changes of groundwater storage, inland seas and lakes, glaciers, permanent snow and other data, necessary for water balance compilation, both on regional and global scales.

1.2.4 Quantitative and qualitative assessments of the effects of man's activities on water cycle and water quality; development of the scientific fundamentals of water quality control.

1.2.5 To create the new methods for measuring computing and forecasting water balance elements with the use of new achievements in electronics, physical chemistry, as well as the use of mathematical models and electronic computers.

1.2.6 Assistance in the training of personnel, as well as technical assistance in the development of networks and scientific research, should be provided; actions should be undertaken for rational utilization and protection of water resources.

1.3 Guidelines for selection of projects and their priorities

1.3.1 The following paragraphs set out the guidelines adopted by the working group for the selection of projects and for ascribing priorities to achieve the stated objectives as outlined in 1.2 above. The working group has concentrated on a broad statement of activities which might provide a framework for definition of specific projects to which the proper priorities should be given.

1.3.2 Only the important hydrological problems requiring international or regional co-operation, and among them those of particular interest to the nations concerned, should be included in the long-term programme.

1.3.3 All projects within the international programme must have direct, or potentially widely usable results that will improve the understanding of hydrological processes and the prediction of hydrological phenomena bearing on future human needs.

1.3.4 Preference should be given to projects related directly to the problems of optimal utilization of water resources in the whole world, especially in developing countries. Scientific studies and especially the practical use of their results should be defined as concretely as possible. Encouragement, sponsorship and support must also be given to large-scale research beyond the capabilities of individual national programmes.

1.3.5 Projects that cannot be accomplished except through international co-operation should be given higher priority than those that can be accomplished otherwise.

1.3.6 IHD projects which are of continuing major interest to the Member States but which remain uncompleted, should be considered for inclusion in the long-term programme at the end of the Decade, and should be subject to the same priorities and considerations as other proposed projects.

1.3.7 Projects that can be readily implemented, improved and enhanced through the use of existing intergovernmental and non-governmental organizations should be given priority over those that require new or greatly enlarged administrative structures.

1.3.8 Projects should only be included where the aim of the work and the time schedule for its realization can be closely defined.

1.3.9 The budget and the sources of financing should be clearly ascertained and available for each project selected.

1.4 Summary of the long-term programme

1.4.1 The aspects of the long-term programme covering practical applications and scientific investigations as put forward in Chapters 2-4 of this report, fall into three main categories:

Water balance and water resource assessments at basin, national, regional and ultimately global levels;

Effects of man's activity on the hydrological conditions, including quantity and quality effects on surface and groundwater;

Application of new developments in hydrology, including sensing, processing and analysing data, forecasting; mathematical modelling and system analysis.

1.4.1.1 Water balances and water resource assessments include:

Measurement and improvement of measurement of resource variables, i.e. precipitation, evaporation, surface water discharge and storage, soil moisture and groundwater storage and replenishment;

Selection and/or establishment of a global network of carefully selected representative water balance catchments, through co-ordinated international action;

Long-term international co-operation to develop technical recommendations on hydrological data processing and computation of water balances (including short period balances); guidance on standardization of hydrological data; establishment of regional water balance trends; extrapolation techniques to the poorly studied basins situated in the same climatic zones, and by means of representative basins.

Compilation of a comprehensive world water balance for the 30-year period 1961-1990.

1.4.1.2 The study of effects of man's activities on hydrological factors, pertaining both to quantity and quality, includes:

Continuing development through international co-operation of a monitoring system of observing control changes in the hydrological régime to record hydrological and other environmental information of world-wide interest, relating particularly to general environmental and hydrological conditions affected or likely to be affected by man's activities. Continued operation of a world-wide network of benchmark and other representative basins is essential for this purpose;

Studying the effects of man's activities in irrigation development drainage, use of groundwater, urbanization and other land use changes, erosion, installation of structures in rivers and lakes, and of waste heat on the hydrological conditions.

Studying and exchanging information on the scientific and technological aspects of self-purification processes, degradation of pollutants in streams, lakes and reservoirs, changes in sediment production and transport and their effects, and the effect of quality changes on the utility of water.

1.4.1.3 Application of new developments in technical hydrology which should be studied and disseminated internationally, include:

Study and exchange of information on new measuring methods and instruments useful for conventional hydrological techniques with new speed and accuracy, and on new techniques necessary for improved hydrological analysis interpretation and forecasting; and adaptation of these for application in developing countries;

Study and exchange of information on means for increasing effectiveness of computer use in data processing, hydrological forecasting and prediction and water resources planning; particularly for those that could be applied in areas where computers are not widely available;

Study and exchange of information on techniques for application to basin modelling related to deterministic and stochastic processes, and embracing also dispersion of pollutants, and other consequences of man's activities;

Development of regional and global hydrological modelling capabilities.

1.4.2 To achieve the objectives of international co-operation set out in paragraph 1.2, the most important needs are described in Chapter 5 - Basic activities for programme implementation. Principal activities under this heading are:

Education and training;
Exchange of information;
Technical assistance;
Regional co-operation.

1.5 Initial list of subjects for the long-term programme

The implementation of the long-term programme would be divided into successive predetermined periods of activity of about five to ten years.

This would give an opportunity to fully assess results of one programme and review and establish the priorities for the following one.

Taking into account the principles of the selection of projects set up in paragraph 1.3, it is proposed that priority should be given to the subjects listed below as especially appropriate for international co-operation during the first of the suggested periods following completion of the International Hydrological Decade.

In defining these subjects, present responsibilities of the international organizations in the field of hydrology were taken into account. It is considered an advantage that, as far as possible, individual projects should be primarily within the responsibility of one or other international organization, in order to facilitate their implementation.

Water balance measurement and assessment

1.5.1 Establishment and operation of adequate measurement networks for water balance variables (2.2.1 - 2.2.1.7).

1.5.2 Improvement and development of network design and measurement instruments (2.2.1.1-2.2.1.7 and 2.3.1 - 4.2.1).

1.5.3 Development and improvement of methods of computation of the elements of the water balance, including groundwater, for short periods for computation of operational balances (2.1).

1.5.4 Research into hydrological régimes and development of methods for computation of its elements for water management design, including the case of inadequate data (2.3.6).

1.5.5 Development of systems for the collection and processing of hydrological information using advanced technology (2.2.2 - 4.2.1 - 4.2.2).

1.5.6 Development of representative and experimental catchments including application of data derived from them especially for use in mathematical modelling (2.3.8 - 4.2.2 - 4.2.3).

1.5.7 Compilation of longer-term regional and global comprehensive water balances including study of multinational river basins (2.3.5 - 2.3.6).

Influence of man's activities on hydrological factors

1.5.8 Investigation of the hydrological effects of man's activities and its assessment (3.3.1 - 4.2.1 - 4.2.3).

1.5.9 Quantitative and qualitative influence on the hydrological cycle of irrigation development in arid areas and establishment of techniques of management (3.3.2 - 4.2.1 - 4.2.3).

1.5.10 Quantitative and qualitative effects on the hydrological cycle of urban and industrial development (3.3.4 - 3.3.6 - 3.3.7 - 3.3.8 - 4.2.1 - 4.2.3).

1.5.11 Long-term prediction of groundwater régimes under natural and artificial conditions (2.3.4 - 3.3.3 - 4.2.1 - 4.2.3).

The new developments in hydrology outlined in Chapter 4 will be of increasing application to the foregoing subjects.

In all the foregoing subjects the basic activities of manpower deployment, education, training and information exchange and dissemination as outlined in Chapter 5 will be necessary to achieve maximum international co-operation.

## 2. WATER BALANCE PROBLEMS AND INVESTIGATIONS AT GLOBAL, REGIONAL AND NATIONAL LEVELS

### 2.1 The need for water balance data

2.1.1 Problems of the water balance must be solved to determine quantities of available and potentially available fresh water resources, including their incidence and variation in space and time. Such assessments contribute to the development and exploitation of resources to optimum advantage in accordance with technical, economic and social criteria, especially in areas of heavy concentrations of population or where other factors make water resources scarce in relation to present or future requirements.

2.1.2 Water balances are best made initially at the catchment level; they can be summed, or in appropriate cases extrapolated, to national, sub-regional, regional and ultimately global levels over long periods of years as well as for individual years, seasons or even shorter periods.

2.1.3 Water balances are fundamental in quantifying water resources; however, it is essential to consider location in relation to demand, means of transmission, water quality, availability of storage, geological conditions, saline intrusion and the effect of man's activities, quite apart from the economic effects and social impact of development.

### 2.2 The activities involved

The main activities associated with water balance and water resource assessments are:

2.2.1 Measurement of resources variables related to quantity

These variables principally include:

precipitation
evaporation
surface water discharge or run-off
soil moisture
storage of water in oceans, inland seas and lakes
storage of water in glaciers and permanent snow fields
groundwater

2.2.1.1 Precipitation can be measured directly by precipitation gauges; these measure only very small point samples and frequently introduce a bias due to the effect of the exposure of the gauge. There is a need for improvement in:

(i) accuracy of measurement of rainfall at a point;
(ii) means of measuring and recording rainfall intensity;
(iii) techniques of selection of gauge sites and of network density commensurate with areal variations in precipitation;
(iv) procedures for transforming point measurements into areal values.

Methods for integrating total areal precipitation indirectly, for example by radar, constitute an important new approach.

2.2.1.2 Evaporation includes evaporation from open water, snow cover, bare soil and vegetative cover as well as transpiration and determines with rainfall the amount of water available for surface flows and groundwater replenishment. Open water evaporation measurements from evaporation pans or tanks are apparently direct, but are subject to bias due to largely unknown influences in the exposure of the instrument. Meaningful direct measurements of actual evaporation are possible from carefully designed weighing lysimeters or from research catchment studies, but such measurements are useful more for defining or testing empirical routine means of computing evaporation. Alternatively actual evaporation can be inferred as the "by difference" term in the long-term water balance.

Evaporation from open water, soil or low vegetative surfaces applied with adequate moisture is determined by the prevailing meteorological conditions; in particular solar radiation, air temperature and humidity and wind may be combined together in a potential evaporation estimate which is generally adequate for hydrological purposes. With low vegetative cover, plant characteristics are only second order effects and can be ignored. When soil moisture becomes limiting, actual evaporation is difficult to determine except by indirect means such as soil moisture measurement. However, for taller crops, plant factors may be more important; in forests in particular the resistance of the trees to moisture loss becomes a first order effect.

Evaporation assessment from snow cover can be carried out by noting the change in the water content of the lying snow at selected points, having due regard to the effect of fresh precipitation and snow melt.

There is need for:

(1) Standardization of techniques for calculation of evaporation from meteorological data for hydrological purposes;

(2) Research into network density necessary for obtaining the basic meteorological data for evaporation estimation;

(3) Research into means of determining actual evaporation from data of potential evaporation;

(4) Standard procedures for transforming point measurements into areal values.

2.2.1.3 Surface run-off is measured by regular or continuous recording of water level or stage of a river at a cross-section which is likely to remain constant, associated with periodic calibration to establish and thereafter to check the stage/discharge relationship.

In the case of large alluvial rivers, movement of beds may occur during high floods and flood discharge measurements must be carried out with high-powered launches and echo-sounding equipment. After these high floods, the stage/discharge relationship must be revised because of changes in cross-section resulting from deposition of sediments during falling floods.

There is a need for:

(1) Effective cheap and reliable means of determining discharge directly;

(2) Extension of networks to ungauged areas;

(3) Development of equipment and techniques for improving the recording of discharge from small catchments;

(4) Improvement in techniques of selecting representative areas for gauging so that results can be applied to similar ungauged areas.

2.2.1.4 Soil moisture is frequently derived indirectly because of the lack of suitable means of measurement other than by disruptive gravimetric sampling. It is often calculated as the "by difference" term in the water balance, or its effect is estimated by such an arithmetic device as the antecedent precipitation index. With improvement in neutron scattering instrumentation it is now practicable to determine precisely at a given site the soil moisture at depths greater than 20 centimetres, and by use of ancillary devices to obtain less accurate but reasonable estimates nearer the surface.

Soil infiltration depends on the mechanical structure and moisture content of the soil as well as on depth of freezing and other parameters. Computation of water losses on infiltration is of importance for compilation of water balances for short periods.

There is a need for:

(1) Research into networks for soil moisture determination;

(2) Adoption of neutron moisture gauges into routine operation.

2.2.1.5 Storage of water in glaciers and permanent snow fields

In areas with settled snow cover, permanent snow and glaciers, it is necessary to determine the water storage in snow cover and glaciers for the period for which the water balance is being made.

2.2.1.6 Groundwater, its replenishment and discharge can be assessed indirectly from changes in groundwater storage by measuring changes in standing water levels with a network of observation boreholes; such information can be converted into storage volumes and hence changes in storage provided that the storage coefficient of the aquifer is known. Aquifer properties may be determined by analysis of natural variations in groundwater levels, as well as of induced changes due to pumping wells. The average groundwater replenishment and discharge of an aquifer may be assessed by determining the discharges of springs as well as the groundwater component (recession curve) of rivers draining the outcrop of the aquifer in conjunction with observation of water levels and quantities abstracted and with some knowledge of the geological and geomorphological characteristics of the area.

Methods of assessing rate and direction of groundwater flow using radioactive tracers and natural isotopes offer considerable potential in solving groundwater problems. Increasing attention is being given to the study of regional groundwater systems and to the use of analogue and digital simulation models to analyse such systems.

There is a need for:

(1) Investigation of losses, because of evaporation at the surface, in transit through the unsaturated zone, and development of techniques for continuous measurement;

(2) Research on network density and extension of networks to ungauged areas;

(3) Effective means of assessing the rate and direction of groundwater flow systems of regional extent;

(4) Study of the chemical changes in groundwater as related to its flow system;

(5) Standardization of techniques of assessing and predicting groundwater resources.

2.2.2 Computation of measurements

It is essential for the measurements to be analysed in a manner which is meaningful for the particular application. For example, for water resources it may be necessary to know the cumulative minimum run-off for various durations and if possible to ascribe a statistical probability to the severity. Furthermore the incidence of run-off is much more conveniently presented by flow/duration curves and by defining the annual extremes of water level as well as the annual maximum, minimum, mean, median and modal flows than by chronological records of daily or monthly flows; these latter are of limited use although they are suitable for digital simulation and for development of mathematical models by computer to optimise water management calculations.

2.2.3 Application of data to water balance and resource assessments

The application of data to specific quantitative water resource assessments may be difficult because:

(i) the record available does not apply sufficiently to the area under consideration;

(ii) all the required variables have not been measured;

(iii) the record is too short; or

(iv) there is no relevant record.

Gauges must be established for the measurement of the necessary variables to correlate where possible with any records already in existence. The problem thus includes design and establishment of guage and instrument networks, collection and processing of data, and correlation, procedures, e.g. run-off-run-off, rainfall-run-off, groundwater levels-run-off.

2.2.4 Trends and patterns of hydrological variables

The computed and analysed data also serve to identify trends and patterns of hydrological variables with space and time. Such applications are required (i) for establishing generalized assessment and design criteria especially for preliminary and comparative studies and to make the fullest use of available data for the whole of an area to which they apply; (ii) for use in medium and long-term hydrological forecasting where historic patterns of changes and extremes are frequently relevant. Both applications can lead to economies in selection, design and operation of water resource development.

2.3 Subjects for long-term international co-operation

The working group consider that having regard to the activities referred to in section 2.2, long-term international co-operation would be an advantage and good co-ordination and guidance desirable in the following spheres:

2.3.1 Standardization of hydrological data

Standard and recommended methods of measurement and recording of hydrological variables and of processing, analysis and presentation of data applying to water resource assessments should be further developed. The machinery for international co-ordination in this field of operational hydrology already exists. However, present techniques must be improved or replaced and much can be achieved by international co-operation. Further scope for co-ordination lies in standardization at the computation, analysis and presentation stages particularly at the sub-regional level. This would be helpful (i) in exchanging data between countries within the sub-region; (ii) for studies involving bi-national or multi-national basins; and (iii) for assisting developing countries to set up systems which exploit methodology already evolved.

2.3.2 Extrapolation techniques

Development of greater co-ordination of procedures and methodology is required for applying data from gauged areas to those with a scarcity or absence of hydrological data.

There is a need for guidelines on the extent to which existing records can be extrapolated beyond the limits in time and space to which the data directly relate. The use of representative basins would be valuable in this connexion.

2.3.3 Establishment of regional water balance trends

Procedures for using processed data and observations to establish trends of regional behaviour of hydrological variables, particularly year by year trends and areal patterns across a region, should be developed and co-ordinated.

Such large scale studies as have been carried out in the past have usually been by a single country; however, this is an area of activity which, by virtue of its scale, would benefit particularly from international co-ordination. Studies on a continental scale should be anticipated in liaison with GARP.

2.3.4 Ground water resources

The resources available from groundwater bodies or in liaison with surface resources are largely recognized, but their use has been restricted by badly-adapted technology, as much in their evaluation as in their exploitation and application of technology in this field to be extended and accelerated.

Hydrogeological cartography provides indispensable data for the evaluation of resources.

Artificial replenishment of aquifers from surface run-off is considered to be of prime importance as a technique for increasing application for groundwater development in the future; it is therefore recommended that experience in the technique gained by member countries can be profitably co-ordinated and exchanged internationally.

2.3.5 Studies of international river basins

Investigation of the hydrological balance of bi-national and muiti-national rivers, large lakes and groundwater basins is most desirable. The technical problems involved are no different from those of basins which are wholly national. However, international co-operation and co-ordination of activities are essential for such international basins. Monographs of great basins should be prepared and revised periodically.

2.3.6 Investigation of hydrological balances and special phenomena in particular climatic zones for water resources management

The temperate zone has been and is being studied in much greater detail than other zones. The working group suggest that an international programme of co-operation would be appropriate for intensive study of certain parts of the tropical, sub-tropical, semi-arid and possibly arid zones, all of which would benefit considerably from more detailed measurement and assessment.

These studies should be made whenever possible in the form of pilot projects in certain developing countries; technical assistance would be required.

2.3.7 Compilation of 30-year comprehensive water balance

The foregoing listed investigations would materially assist in compiling a comprehensive world water balance for the 30-year period 1961-1990. To be of practical use, such a global compendium must be suitably sub-divided so that meaningful information and indications are available for all areas. The end result would thus be a world-wide inventory of potential water resources of assistance to planning large-scale future development.

2.3.8 Selection and/or establishment of representative basins

A limited number of designated representative catchments should be selected and distributed throughout the world in broad hydrological regions and including the principal topophysiographic conditions encountered in areas where water resource development is needed. These basins should be gauged reliably and comprehensively, and the measurements recorded and processed in a standard form. The programme for long-term co-operation should include the means for the selection and where necessary the setting up, of such representative basins; also the co-ordination of the processing, analysis and dissemination of the resulting data.

## 3. EFFECTS OF MAN'S ACTIVITIES ON HYDROLOGICAL FACTORS

### 3.1 The need for and scope of study

Man's development of water resources has resulted in great economic and social benefits by providing favourable environments for his agriculture, his industry and his living conditions; but, if not carefully planned, may have adverse effects also. The assessment of man's management activities on the hydrological cycle therefore is central to the problem of modern hydrology especially considering the increasing scales of river run-off regulation, groundwater utilization and general changes in the environment. Likely developments projected over the next few decades are much greater than those already realized.

Simple prudence requires that changing parameters of water quantity and quality be understood both locally and globally, and therefore that systematic observations be carried out and resulting accurate predictions of the consequences be made and disseminated. Quantity shifts and gross quality parameters are important, but exotic and trace chemicals can be toxic to both plants and animals. Both biological and physical processes may concentrate these to dangerous levels from their water environments. Thus the subject of water quality takes on new levels of subtlety and sophistication. The trends in agriculture towards mechanization and increased environmental control, especially the use of pesticides, and the concurrent major movements of people from agriculture to urban and industrialized activities, will both give rise to increasingly dramatic changes in water quantity and quality. Man's intended or unintended intervention in atmospheric processes; such, for example, as precipitation changes resulting from changes in condensation or freezing nuclei and changes in radiation due to particulates in the atmosphere, could have effects on the hydrological cycle which are so far only dimly understood.

A better understanding of the level of water quality required for various uses is greatly needed. The effects of quality on man and on biology as well as for agriculture and industry must be kept in mind. Man made lakes and irrigation schemes undertaken mainly to benefit mankind can also create secondary conditions favourable to disease vectors and thereby be instrumental in introducing these diseases into areas where they did not previously exist. Impoundments also attract influx of people who settle in unsanitary conditions around the lakes, giving rise to epidemics of various diseases. Public health and sanitary services (particularly safe water supply and sanitary disposal of excreta) must therefore be planned concurrently in water resources development projects.

### 3.2 Extent of effects of man's activities

Man-induced hydrological changes are most likely to be apparent at the more local levels but there are also significant changes at national and sub-regional levels (e.g. changes in régimes of large rivers) and oceanic levels (e.g. changes in nutrient supply or sediment to beaches owing to changes in river régimes). Global aspects are less apparent, however. Some pesticides are already pervasive throughout the entire ocean. Constant vigilance must be maintained in order to guard against subtle and unexpected global effects.

### 3.3 Content of a long-term programme on the effects of man

The long-term programme relating to man-induced changes in the hydrological cycle should be concerned with both quantity and quality; not only average annual and long-term changes, but short-term (daily or monthly) changes as well. The principal components of a programme on the effects of man's activities on hydrological factors of the environment should be:

(a) System for observing control change in the hydrological régime;

(b) Effects of irrigation and drainage development;

(c) Impact on groundwater;

(d) Effects of urbanization;

(e) Changes in basin use;

(f) Changes resulting from structural works;

(g) Effects of waste heat;

(h) Studies of diffusion and dilution of waste water in rivers, groundwater, lakes and reservoirs and self-purification processes;

(i) Changes in sediment production and transport.

The main task of international co-operation is organization and implementation of a co-ordinated plan of laboratory and theoretical investigations in order to define the interrelation of water and other elements of the geographical environment that will facilitate purposeful water management in accordance with needs of all cultures. Among the aspects of this large and complex topic, the following items are proposed:

(i) changes in the water cycle resulting from:

(a) intensive irrigation development

(b) intensive drainage development

(c) urbanization resulting from large density population

(ii) system for water protection against pollution.

Special emphasis should be given generally to effects of irrigation development, especially in arid areas, drainage of areas receiving excessive moisture, study of self-purification processes, and water quality control.

3.3.1 System for observing control changes in the hydrological régime

Continued development of an observation system which could reference environmental changes of world-wide interest should be carefully planned and implemented primarily through co-ordination of the efforts of concerned countries. Continuation of the network of benchmark and other representative basins referred to in paragraph 1.5 would provide basic control data or indicator data on changes. The data collected should be expanded to include information on quality and other environmental parameters. Such data should be published by the countries concerned and made available on a global basis.

Other observation stations should be carefully considered by experts. Because of the expense, these need to be very carefully chosen. One of the possible important parameters relates to changes in transport of sediments and dissolved solids to the oceans. This argues for a system of river-mouth stations on at least the major continental rivers. A reference network of lakes may also be desirable.

Such a system needs to be very carefully considered. Costs are going to be significant, and greater care needs to be exercised in selection of stations, including their location and the choice of observed variables on a sound scientific basis.

3.3.2 Effects of irrigation and drainage development

One of the most significant man-made changes results from diversion of river waters for irrigation use. Studies by a number of international organizations (for example, FAO's Indicative World Plan) emphasize the importance of irrigation in meeting future needs for food and other agricultural

production. Irrigation works will be very likely doubled in the next few decades. It is well known that diversion for irrigation changes hydrological régimes of rivers both as regards quantity and quality. Normally sediment transport is reduced and dissolved solids are concentrated. Groundwater levels may be dramatically raised and groundwater salinity increased; ecological changes may also be induced both in irrigation areas and in the associated rivers themselves. Increased use of pesticides and fertilizers is visualized on contiguous lands. For these reasons, irrigation projects have received increasing criticism from ecologists. Intensive works being constructed on excessively wet and swampy lands for agricultural purposes will influence water balance and transfer processes for both surface and groundwater. Accepting the need for increasing irrigation, it is also recognized that increased information and understanding must be obtained about hydrological consequences. It is necessary that the impact on the water cycle be investigated with the view to define this optimal régime to minimize adverse effects.

There will be a need for generalizing and publishing information on predictive techniques based on both theory and empirical observations of actual projects. Systematic monitoring of a limited number of pilot projects prior to, during and following development, should be encouraged as a valuable activity in an international programme. Main components should include water régime and water balance transformations for arid areas with developed irrigation and for drainage of areas receiving excessive amounts of moisture.

3.3.3 Impact on groundwater

Groundwater will constitute an increasingly important source of water supply for irrigation and for municipal and industrial purposes, especially with the development and dissemination of improved technology as envisaged in paragraph 2.3.4. The use of groundwater may affect quantity and quality of surface supplies downstream from cities or industries through changes in groundwater régimes. Irrigation recycling tends to concentrate salinity within the aquifer. Return flows from all uses and atmospheric pollution and nutrients (nitrates, primarily) and possibly trace substances to groundwater supplies. Urbanization may reduce recharge areas for aquifers and hence diminish the long-term availability of groundwater. Urbanization may reduce recharge areas for groundwater aquifers; on the other hand, artificial recharging by surface flood flows and from reclaimed industrial and municipal waste waters can be expected to increase.

The nature of the aquifer and the recharge mechanism can have significant effects on quality changes. Limestone and volcanic rock aquifers may remove only a few pollutants, whereas seepage through absorptive and adsorptive clays may remove most of them. Increasingly important will be subsidence resulting from groundwater utilization, and intrusion of saline waters.

A great deal is known and published already about impacts of man's utilization on groundwater quantity. Less is known about quality, especially the effects of seepage of polluted waters to water tables. Efforts should be concentrated on identifying those effects that are new; for example, the results of new components in waste water, and the development of predictive models for quality and quantity, utilizing international expert groups. Encouragement should be given to countries to establish specific reference studies of groundwater changes under urban, industrial and agricultural development conditions.

3.3.4 Effects of urbanization

Effects of urbanization on hydrology have not been adequately studied. There is, however, a growing interest in this topic. This is timely, because of the greatly increased urbanization foreseen in all countries. A well recognized, but not well understood effect, is the change in quantity and timing of run-off resulting from changes in land surface infiltration and roughness characteristics. Conditions are affected by changes in stream channel geometry, particularly during flooding.

Quality changes are extremely significant as the result of municipal and industrial use, subsurface disposal of industrial waste, and waste water return; also the results of the flushing action of flood storms are important.

Efforts need to be made by international action to widely disseminate new information being generated by research among hydrologists through publications and seminars. Evaluation and interpretation of urbanization effects would also appear to be an area for technical assistance. Encouragement of detailed pilot studies by countries of a limited number of typical urbanizing areas in order to

identify changes, by means of representative and experimental basins or areas. International exchange of results would be a useful activity, provided the studies are well designed and executed.

3.3.5 Changes in basin use

There will be continuing changes in catchment use. In some places, overgrazed catchments may be restored and some areas now used for grazing will be converted to rainfed and irrigated agriculture. Similar changes will occur with forested catchments. The most extensive reallocations of catchment use occur in the tropical and sub-tropical savannas and rain forests, where the hydrological results are probably least well understood. The present network of Decade and experimental basins would be selectively reviewed on the basis of need and performance and continued as appropriate. Additional experimental basins particularly in the areas mentioned above, may need to be designated.

3.3.6 Changes resulting from structural works

Various kinds of structural works including reservoirs, barrages, and training and poldering levees produce effects on water quantity and timing also, in some cases, on quality. Quantitative effects of reservoir storage are well understood; effects of training and poldering levees, especially where much of the run-off originates locally are understood less well. Quality effects of reservoirs need increased study. Other kinds of structures may result in quality effects, chiefly by bringing about changes in erosion and sediment transport characteristics of streams.

The important issues for which continuing or expanded international exchange of information might be merited include reservoir effects, may have limited global application and might be investigated on a sub-regional basis or by individual countries.

3.3.7 Effects of waste heat

One of the major problems facing all countries results from the effects of waste heat disposal on streams, lakes, bays and estuaries and underground reservoirs. Most of the changes will occur as the result of cooling requirements for electrical generation. These thermal loads will double in most countries every eight to ten years. In addition, many other industrial processes release waste heat to water sources.

Consequences of changes in water temperature régimes appear to be largely ecological. This is not entirely the case, however, because increased heat changes the utility value of water as a source whether it be groundwater or surface water. Increased temperature increases evaporation from streams and other open water surfaces.

Unlike many pollutants, heat is not conserved in the hydrological cycle, but is transferred primarily to the atmosphere. The principal scientific problem relates to the nature and rate of transfer resulting in the cooling of heated streams and other water bodies. There may be secondary effects, for example, on flow characteristics.

The most useful activity for a long-term programme would be information exchange about heat transfer and circulation effects resulting from waste heat inputs under various kinds of stream and estuary conditions and in reservoirs, lakes and the ocean. It is important that hydrologists be able to predict the nature of the heat régime in sufficient detail to ensure adequate assessment of economic and ecological consequences. Research and information exchanges should be co-ordinated with the International Biological Programme and other international environmental and biological activities.

3.3.8 Studies of diffusion and dilution of waste water in rivers, lakes and reservoirs and self-purification processes

Specialists of many countries are facing the problem of calculation or prediction of future changes in the chemical content of water resulting from man's activities. Increased use of fertilizers and pesticides in modern agriculture is one important example.

The diffusion of pollutants deposited into rivers, lakes and reservoirs, depends on the quantity of water available, velocity of flow and other hydrological parameters of the recipient water bodies. Studies of the mechanism of diffusion and dilution of waste water, and development of methods for

computation of the extent and degree of dilution of polluted areas, are important for the development of safeguards against water pollution.

To solve these problems, studies are necessary on the mechanisms of physical, chemical and biochemical processes relating to particular pollutants in waste waters in rivers, lakes and aquifers.

Some polutants react chemically with others, create sediments or are removed from the water body. Others create new substances, some of which may be toxic to plants and animals. A third group of pollutants are assimulated by living bodies, in which case self-purification takes place. Knowledge is needed concerning the persistence of certain chemicals and biological organisms especially where re-use can occur.

One of the objectives of future co-operation in this field is to generalize the experience gained by the countries conducting studies of this kind and to establish the best methods, including the use of computers, for the evaluation of diffusion areas of pollutants.

The long-term international programme should include studies of the mechanism of self-purification as well as the computational methods for estimating self-purification ability methods; these are of great importance for prediction of water quality.

3.3.9 Changes in sediment production and transport

Activities of man such as farming, including grazing of domestic animals, and construction of works influence the production of sediments; others such as reservoirs and diversion works influence erosion and transportation of sediments in rivers.

Sediments have important direct effects on water quality. They influence treatment processes, including recycling, erosion and sedimentation also affect ecosystems in many ways such as providing transport media for nutrients (notably phosphorus), changing radiation available to aquatic vegetation and smothering effects on the transpiration of aquatic plants and animals. Hydrologists need to understand these implications and need to be able to predict changing sediment production and transport régimes with sufficient accuracy so that adequate prediction of engineering and biological consequences can be made. Measurement and understanding of sediment production and effects is important area for technical assistance and information exchange, especially in those countries where sedimentation processes are particularly important. An increasing emphasis should be placed on the study of basic soil erosion processes.

## 4. NEW DEVELOPMENTS IN HYDROLOGY

### 4.1 The need for and scope of study

4.1.1 In recent years, several new technologies applicable to hydrology have been rapidly developed. These include nuclear techniques in hydrology, improved sensing and processing of hydrological and meteorological data, mathematical modelling of various hydrological elements and systems analysis. Scientific and operational hydrology have greatly benefited from the application of digital and analogue computers. The further development and effective application of all these new methods and techniques, which have come in part from outside hydrology, will greatly benefit from international co-operation of the scientific hydrological community at regional and global levels.

4.1.2 In the last decade, mathematical models for various hydrological phenomena have been developed. Their development and application should assist in solving many of the scientific and practical problems, including principally water balances, hydrological forecasting, water systems analysis, and investigation of the effects of man's activities on quality and quantity of waters. The improvement and international comparison of different hydrological models will promote their practical use at national level, as well as in multinational river basin studies. Due attention should be devoted to modelling of the global water cycle as a part of the process of monitoring the global atmospheric variables.

4.1.3 As the lack of input data frequently causes difficulties both in classical studies and in the application of hydrological models, international co-operation in data assessment and processing is of great importance. The experience gained during the IHD should form a basis for such co-operation.

4.2 Subjects for long-term international co-operation

Having regard to the foregoing remarks, the Council considers that long-term international co-operation in the following fields is required:

4.2.1 Measuring methods, techniques and instruments

Development of new measuring methods, techniques and instruments includes:

(i) use of nuclear and physiochemical techniques for tracing both surface and groundwaters;

(ii) use of neutron and gamma techniques for measurement of water in the unsaturated and saturated zones;

(iii) automatic data logging;

(iv) use of radar, particularly for aerial assessment of precipitation;

(v) improved methods of measuring meteorological and hydrological variables which control evaporation and dissemination of generally accepted methods for computation of aerial evaporation;

(vi) development of remote sensing techniques for hydrological application and water resources observation satellite programme, etc.

4.2.2 Computer use in data processing

Increase the effectiveness of computer usage in data processing, hydrological calculations and in the planning and operation of water resources systems; consideration should be given to the development of universal hydrology - oriented computer languages and promotion of their application.

4.2.3 Basin models

Development and comparison of hydrological basin models which may be used in different climatic and physiographic conditions, and promotion of their application, e.g. by means of standard computer programmes, on national and regional levels. Bearing in mind that the hydrological cycle is now a hybrid of natural and man-made forces, development of models to predict hydrological consequences of man's activities, e.g. of major water-resources projects.

4.2.4 Other hydrological models

Studies on other hydrological models of great practical importance are:

stochastic models of hydrological time-series models of storage systems;

methods of modelling heat and mass dispersion processes in streams, lakes and estuaries;

their application to hydrological analysis and forecasting.

4.2.5 Modelling of regional and global atmospheric water cycle

Development of the methods of modelling of the regional and global atmospheric water cycle, in conjunction with other international programmes, e.g. World Weather Watch (WWW) and Global Atmospheric Research Programme (GARP) and modelling of ecosystems (IBP).

5. BASIC ACTIVITIES FOR PROGRAMME IMPLEMENTATION

Activities in support of the study and application of hydrology are essential for assuring the development of any hydrology programme and for adequate diffusion of its results. These activities consist mainly of programmes of education and training, exchange of information, technical assistance and regional co-operation. They should always make full use of existing governmental and non-governmental organizations and administrative structures.

5.1 Education and training - manpower needs

5.1.1 Hydrology, as the science which studies the hydrological processes and their relation to the environment, is an essential prerequisite for planning, design and operation of water resources development.

5.1.2 One of the most important supporting activities in the field of hydrology is the promotion of education and training. The training of hydrologists, technicians and observers has been given a high priority in the programme of the IHD and should continue to be one of the basic contributions to the development of hydrology.

5.1.3 The main tasks of the long-term programme in the field of education and training are:

supporting the high standards of technical and scientific basis of hydrological personnel all over the world;

promoting the use of the possibilities of the educational institutions in developed countries for the training of skilled hydrological personnel from developing countries;

promoting training and raising the qualification of all levels of hydrological personnel by international courses, regional courses, and particularly by national training centres in developing countries;

development of correspondence courses;

preparation and dissemination of universal (typical) curricula for the training of hydrological personnel at various levels;

study and dissemination of experience through the use of visual aids, films, etc. as well as preparation of education programmes in hydrology.

One of the main objectives of a long-term international programme of education and training in hydrology should be the development of courses aiming at reducing shortages of critical trained manpower.

To this end, one of the first steps is to promote the world-wide establishment and acceptance of hydrology courses in such fields as water resources planning, development and management. To attain these objectives, it is necessary to develop educational methods, curricula and materials, and field training programmes which could satisfy the increasing demands from developing countries.

Such programmes will be facilitated through the teaching of standard methods of measurement of hydrological parameters for the inter-comparison of results. This will also be beneficial for exchanges of professors and post-graduate students.

5.1.4 Future training programmes in hydrology should be geared to the differing needs of the various countries whether they be for full-time hydrologists or scientists from other disciplines with a supplementary knowledge of hydrology. Hydrology should be considered as an integrating science. It can reasonably be expected that the need for hydrologists will continue to grow. It is important that the continuing needs of countries for hydrological training programmes should be realistically assessed and periodically reviewed.

5.1.5 New training problems are also arising in connexion with new environment-related problems, particularly in water quality and the recycling of used water. Biological and physical pollution and the relation between water availability and national economic growth require intensive development of national planning of the utilization of natural resources on a long-term basis.

Future training programmes therefore should emphasize the development of system analysis and model techniques and their combination with analogue and digital computers.

5.1.6 Training seminars play an important rôle and should continue to be organized. These seminars should deal with such things as the computation of large-scale water balances; the effect of man on the hydrological cycle; and problems of water quality with regard to pollution, purification and re-use.

Training courses - both for professionals and technicians - should cover procedures and methods for the extrapolation of data to ungauged areas and procedures for the collection, computation, analysis and presentation of data for regional and international use.

5.1.7 Besides the current post-graduate training programmes, experience has proved the need for the establishment of more short-term refresher courses in specialized subjects.

5.1.8 Introductory or supplementary courses could be provided by correspondence, radio or television.

5.1.9 The growing demand for application of both analogue and digital computers in hydrology will necessitate the availability of suitable hardware and soft ware and for research and training purposes.

5.2 Exchange of information

The exchange of information and experience between scientists in different countries is a necessary part of a programme of international co-operation. Improvement of existing means of exchange and encouragement of regional co-operative arrangements should be emphasized.

The programme should be carried out through:

conference and symposia;

compilation, publication and exchange of global and regional information;

expert missions.

5.2.1 Conferences and symposia

International meetings for exchange of technical and scientific information of international importance as listed in chapters 2, 3 and 4 should be organized and supported. Encouragement should be given, in addition to the organization of conferences and symposia at regional level.

5.2.2 Compilation, publication and exchange of global and regional information

5.2.2.1 National publication of hydrological data should be encouraged to satisfy national scientific and practical needs, including observational data from monitoring networks and from representative and experimental basins.

5.2.2.2 At the same time, appropriate international agencies should prepare and publish selected material in the following categories:

information on past and ongoing research, i.e. summaries of research programmes, bibliographies, etc.;

multilingual thesauri, handbooks and manuals;

appropriate compilations of meteorological, hydrometric and environmental data, including outstanding hydrological phenomena;

standard hydrological maps.

A soft ware library for the compilation and storage of available computer programmes should be established.

5.2.2.3 In particular, publications should be issued to provide information on major activities of the long-term programme, as set out in chapters 2, 3 and 4, and as summarized with priorities in chapter 1.

Arrangements should be made to develop systems of exchange of information on the activities of international interest, described in the previous chapters.

In order to improve exchange of hydrological information, particular attention should be given to: standardization of cartographic procedures; preparation of catalogues of research projects; diffusion

of information and equipment and installation of audio-visual aids, exchange of education and research; and the establishment of an international registry of experts in hydrology.

5.2.2.4 In order to improve availability of hydrological information the outlets for the publications arising from the programme should be co-ordinated to agree with the long-term responsibilities for programme implementation. National, technical and scientific publications should be encouraged and should be issued through national channels.

5.3 Technical assistance

5.3.1 Each country must ultimately become responsible for implementing its own hydrological activities. Because of limitations of manpower and technical resources in some countries, support for these activities is one of the main purposes of technical assistance, together with the development of opportunities for training of hydrologists, technicians and other water specialists, as required by local conditions.

Technical assistance should therefore be provided for the establishment, maintenance and improvement of national and project-related observational networks, and the organizations for processing and publishing hydrological data.

Assistance should be given to establish institutions for hydrological teaching and research in developing countries and the promotion of their use for training.

5.3.2 Short-term expert missions may be sent to Member States requiring assistance in the preparation, execution and evaluation of their programmes for hydrology and water resource development and including related educational and research activities.

Co-operative field projects may be organized for the study of major river basins, arid and tropical humid zones and natural disasters affecting regions, preparation of monographs on the results of these studies, and pilot projects established to verify and demonstrate the use of modern scientific methods and equipment in hydrological studies.

5.3.3 The participation of hydrologists from developing countries, in sessions of working groups, symposia, seminars, round-tables, etc., related to the long-term programme should be supported.

5.4 Regional co-operation

5.4.1 The IHD has stimulated many bilateral and multilateral investigations, particularly among countries sharing river or groundwater basins. One of the objectives of the long-term programme is to encourage countries to undertake these activities and to increase the assistance to be provided to them.

5.4.2 The practice of organizing periodic regional meetings of the National Hydrological Committees should be continued and supported. These meetings will serve to identify regional projects and to make concrete suggestions for their implementation. Support should also be provided for regional conferences, meetings, training courses, working groups, seminars, etc., organized by other organizations interested in hydrology.

5.4.3 Bilateral or multilateral co-operative studies should be made of important rivers, groundwater basins, representative and experimental basins, etc., for phenomena of mutual concern.

Regional projects should be developed as a contribution to global studies included in the long-term term programme, such as:

computation of regional water balances;

compilation of a 30-year comprehensive water balance;

development of extrapolation techniques from gauged to ungauged catchments.

5.4.4 Encouragement should be given to the development of training, research and exchange facilities, such as documentation centres, at regional and sub-regional levels.